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PRESENT ACTIVITIES OF THE COAST AND GEODETIC SURVEY*

BY

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Superintendent of the United States Coast and Geodetic Survey

There are various reasons why the head of the Coast and Geodetic Survey should be particularly glad to speak to an association of his colleagues in the engineering profession in Philadelphia. Philadelphia stands in a certain maternal relationship to the Coast Survey for, when the question of organizing a survey was up, the government turned to members of the American Philosophical Society for counsel and guidance. In response to the circular of the Secretary of the Treasury, calling for plans for the conduct of a survey, thirteen plans were submitted. These were fortunately referred to the then Vice-president of the American Philosophical Society, as Chairman of the Committee, to decide on the adoption of the best plan. The Committee endorsed the scientific methods proposed by Mr. Hassler who became the first Superintendent of the Survey.

It was a good example to set, but one which the government has not always pursued, to have the fundamental principles on which a work of applied science should be done, submitted to scientific men for consideration. To engineers it may seem as though no other way could have been chosen, than the one that prescribed a trigonometric survey as the basis of an extended survey, but as a matter of fact other methods were proposed. These things occurred in 1807, from which date it is seen that this Bureau is old in years, but facts will show that it is young in spirit, and strives to march in the van of progress, to lead where it can, and to follow only where it must. When the plans for a survey were made the Coast of the United States extended from Maine to Florida. The Floridas, much of the Gulf Coast, the Pacific Coast and Alaska were geographical conceptions outside of what is now the United States. At the present time the work of the Survey has been extended to the Philippines, the Hawaiian Islands, and other islands under the jurisdiction of the United States.

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In brief language the following extract, from an official publication, describes the duties of the Survey:

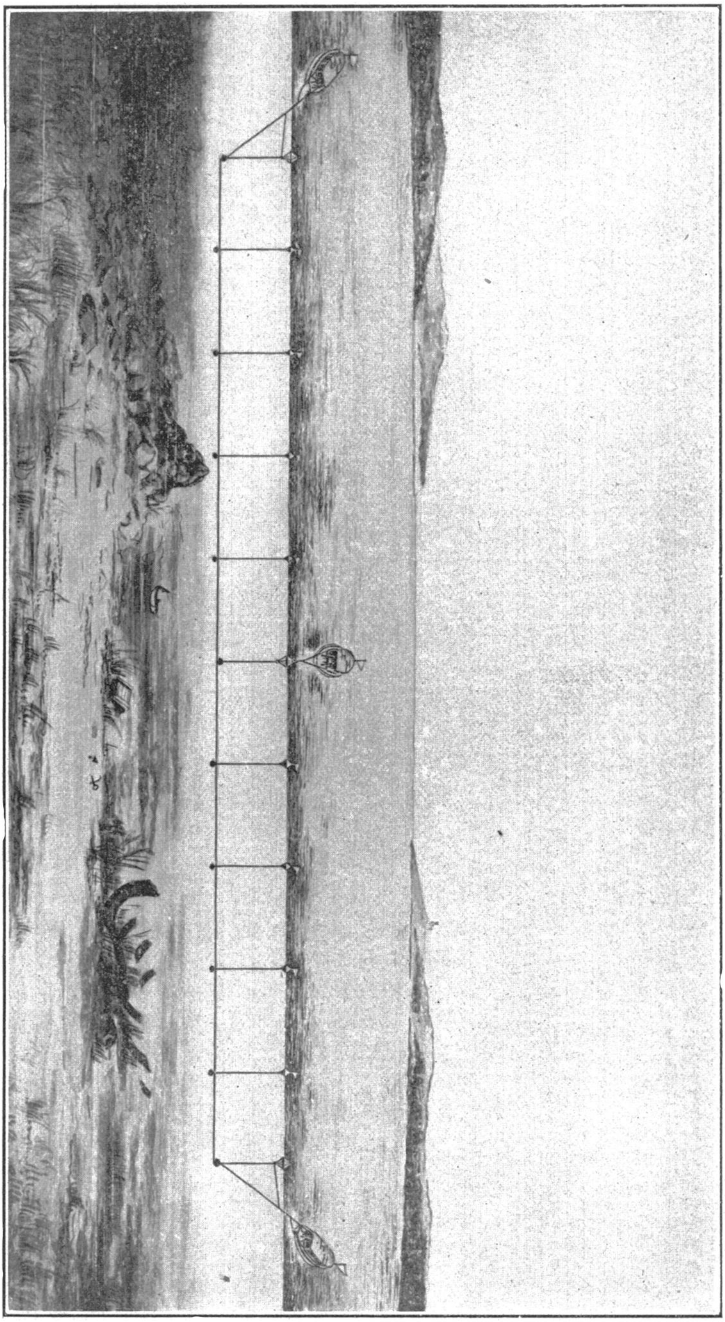
> "The Coast and Geodetic Survey is charged with the survey of the coasts of the United States, and coasts under the jurisdiction thereof, and the publication of charts covering said coasts. This includes base measure, triangulation, topography, and hydrography along said coasts; the survey of rivers to the head of tide-water or ship navigation; deep-sea soundings, temperature, and current observations along said coasts and throughout the Gulf and Japan streams; magnetic observations and researches, and the publication of maps, showing the variations of terrestrial magnetism; gravity research; determination of heights; the determination of geographic positions by astronomic observations for latitude, longitude, and azimuth, and by triangulation, to furnish reference points for State surveys.
>
> "The results obtained are published in annual reports, and in special publications; charts upon various scales, including sailing charts, general charts of the coast, and harbor charts; tide tables issued annually, in advance; Coast Pilots, with sailing directions covering the navigable waters; Notices to Mariners, issued monthly and containing current information necessary for safe navigation; catalogues of charts and publications, and such other special publications as may be required to carry out the organic law governing the Survey."

It is because of the vastness of the subject that this paper is intended to touch upon present progress, conditions, and problems only and much that would be of interest and importance must be omitted.

The principal business of the Survey is making charts of the coasts. If there were no changes in the depth of channels, if the artificial aids to navigation remained fixed and unchanged, if the aspect of the shores from the navigator's viewpoint remained the same, if the draft of vessels remained the same, if the variation of the compass remained the same, if, in short, things were not as they are on this changing globe, or the world were commercially fossilized, a survey once made would last forever. The actual facts are different.

Time was when it was a matter of small concern what dangers to navigation might lurk at a depth of more than 20 feet, but with the increased size and draft of vessels and their enormous cost, a revision and reëxamination of much of the old hydrography by new methods has become necessary. The channel sweep and wire drag now supplement the lead. After these new appliances have swept the bottom the Survey may look with equanimity on the evolutions of ten-million dollar battleships in our waters.

With every new chart that is published the Office assumes the responsibility of keeping it correct, showing the changes in the magnetic variation, in the depths, and in the landmarks. This necessity,



Coast and Geodetic Survey, Wire Drag.

For locating sunken rocks and like dangers to navigation which the usual methods of sounding fail to discover. The long wire, suspended at any desired depth from specially designed buoys, is dragged through the water by two or more launches. The length varies from 100 to 12,000 feet.

affecting the great number of charts that are published, engrosses the energy of the small force at the disposal of the Survey to so great an extent that it has become necessary to simplify the charts in many particulars. Not only do the results of these extended activities flow into the Office, but through the coöperation of the Corps of Engineers of the Army, its surveys for improvements are at once furnished to the Office. A hearty coöperation now exists between most Bureaus of the National Government.

When the publication of charts was first commenced they were engraved on copper in minute detail and with all the skill and beauty which the engraver's art could command. This system was followed until the problem of keeping the charts correct became one of overshadowing importance, on account of the detail shown on them not absolutely necessary for the navigator.

The first survey of the coasts having been completed it appeared possible also to reduce the number of charts by a rearrangement. Careful consideration of the economics of the problem showed that by such a rearrangement of limits, and by simplification, it would be possible to meet the ever increasing demands made on the Survey. These changes involve at the outset much work, but by following a consistent policy they can be brought about gradually without too great a strain on the resources of the Survey.

The tidal and current data hold a prominent place on the charts. In regard to the former, the charts give ample information, and this is supplemented by the publication of tide tables covering the world and which for completeness are unequalled by any publication devoted to this purpose. The Survey has recently completed a tide predicting machine of great scope and power. The theory of tides has been illuminated and advanced by researches made in the Bureau so that in this particular the Survey holds its place in the front rank.

In regard to currents, it must be said that much remains to be done, but this work has been delayed and crowded aside by the more pressing needs of commerce in other directions.

Just as the tide tables supplement the charts so do the sailing directions, designated as Coast Pilots, and to the preparation of which the labors of a number of experts are devoted.

Magnetics. It is a part of the regular duty of the Survey to show on the charts the magnetic declination and its annual variation. Unfortunately, the laws governing this phenomenon are unknown. Of late years Mother Earth has made a sudden acceleration of the rate of variation. Thus, along the coast of Maine, the change has been from 3 to 6 minutes per annum and, on the far western coast, from 2 to 5, while the line of no variation persists fairly well in staying in one place. It is, therefore, part of the Survey's duty to record these eccentricities of the needle. As an important auxiliary to their detection, the Survey maintains a magnetic observatory in Vieques, an island lying to the east from Porto Rico; another in Maryland, a third in Arizona; one in Sitka, and one in the Hawaiian Islands. In all of these, observations are made by continuous photographic registration. All the world is busy with similar observations, and whenever a scientifically equipped expedition, as for example the recent ones to the Antarctic, starts out, there is a general coöperation between the different governments of the world for the purpose of making simultaneous observations. It is to be hoped that sooner or later the mystery will be fathomed so that predictions of what is going to happen can be made.

The Triangulation and the Figure of the Earth. In so extensive an undertaking as a trigonometric survey of the coasts and interior of our country it inevitably happened that surveys were made in detached localities, in Maine, in Florida, on the Gulf, and on the Pacific coast. Each area was referred to some local datum just as detached leveling would be. Gradually, these separate surveys were connected and it became necessary to adopt an origin of coördinates in reference to which all geographic positions should be expressed.

Every extended triangulation, whose determined positions and relative bearings are to be given is developed on some adopted spheroid of reference. In the beginning Bessel's spheroid was used by the Survey. Later, the geographical positions were computed on Clarke's spheroid. An enormous amount of computation is involved in shifting from one to another and yet it is desirable to utilize all increase in knowledge of the size and figure of the earth.

In order to meet the difficulties presented by these conditions it was decided to separate the refined investigation of the figure and size of the earth from the practical requirements of using a spheroid, which should be sufficiently close for the practical requirements of the surveyor, the engineer, and the geographer. It is believed that the Clarke spheroid, of 1866, which was adopted by the Coast and Geodetic Survey, satisfies these latter requirements for the whole American Continent. The Survey next selected a particular point in the triangulation and a direction, and now, when triangulation is spoken of as being on United States Standard Datum, the meaning is that the triangulation has been referred to Clarke's spheroid on which this particular point has a definite position.

Not only the Coast and Geodetic Survey triangulation, but that of the Lake Survey also, has been referred to this datum and wherever the topographic work of the Geological Survey has been connected with the triangulation of the Coast and Geodetic Survey it is equally referable to this datum. In this way has been achieved a homogeneous system of geographical coördinates for the vast domain of the United States, and it is not unlikely that Canada and Mexico will continue the same system.

It is not necessary to point out the practical value of a trigonometric survey. New uses for it continually arise. Witness the cadastral survey of Greater New York which is based on U. S. triangulation. The Oyster Surveys of the various States utilize the trigonometric points for the delimitation of the oyster-beds. The Coast Artillery is supplied with data which are used for fire control, and, in general, the network of triangulation forms a basis for coordinating all topographic and economic surveys, and thus the work accomplished is forever increasing in value and usefulness.

Among the unforeseen applications was the demonstration of the precise amount of the displacement of the earth's surface, by the San Francisco Earthquake along the fault line, and the extent of the movement at right angles to it.

Until about six years ago the method of deriving the figure and size of the earth from triangulation was to deduce it from measured arcs of parallels and meridians. That is, after the length of a meridional arc or parallel had been measured, the angle which its termini subtended was astronomically determined. But owing to the irregular distribution of masses on and within the earth's crust the actual direction of the Zenith differed from the geometrical Zenith of the spheroid of reference. This well-known error, called the deflection of the plumb line, was assumed to average out in a large number of arc measurements. At any rate no correction for it was applied.

A great many years ago, Archdeacon Pratt, while studying the pendulum observations made in India, reached the conclusion that wherever there were visible mountain masses such as the Himalayas there was a corresponding defect of mass in the earth beneath, but it was reserved for the Coast and Geodetic Survey to extend and apply this theory in the computation of the size of the earth from arc measurements by introducing into Geodesy what is now known as the principle of Isostasy. This principle is that the matter composing the earth's crust to a certain depth has a tendency to adjust itself to a condition of hydrostatic equilibrium or has done so. Stated in another way, upwards from a certain depth below sea-level, each unit area has the same amount of mass above it whether we measure to the summit of mountains or merely to sea-level.

By trial computations, the most probable depth to which this compensation extends, was found to be about 122 kilometers, or seventy-five miles. Note how the work of the geodesist trenches on the domain of the geologist and geophysicist.

The hypothesis of isotatic compensation having been introduced, the effect of the visible topography for a distance of about 2500 miles was computed for each of the primary triangulation stations of the Survey, and the deflection of the zenith, previously referred to, was corrected at each station. Then the spheroid, whose surface most nearly agreed with the surface of the United States, was deduced and this gave the corrections to Clarke's spheroid. It is safe to say that the values for the compression and semi-diameters of the earth, resulting from these computations, are the most accurate known. It may be added that, when the results of this work were presented two years ago to the International Geodetic Association in London, the Americans were congratulated on having made a new epoch in Geodesy.

The Pendulum. While one must rely on trigonometric observations to determine the size of the earth its figure can be determined by gravity observations, that is, by the pendulum alone. It is, therefore, a very important auxiliary in a Geodetic Survey. For the purpose of comparison the observations made with the pendulum must be reduced to sea-level. The manner of reducing them is one of the moot questions in Geodesy. Now, the recognition of the existence of isotatic compensation, which has been proved by purely astronomic methods, compels one to take it into account in the pendulum reductions. The method of reduction just introduced in the Survey not only does that, but, also, for each station, takes into account the effect of the attraction of visible masses for the whole earth. This is a great stride in advance; but the inevitable logic of this process has not been received abroad with open-minded enthusiasm. The correctness of the method has been proved for gravity work in the United States, and it is for others to show that it does not apply to the rest of the world.

The International Geodetic Association. To make a new epoch in science is no mean achievement; but mention has already been made of the compliment paid to the Americans at the last meeting of the association in London. This association exists by virtue of a formal convention between the great powers of the world. It is an official organization whose object is to promote knowledge of the size and figure of the earth. Canada, the United States, Mexico, and Argentina belong to it. So do Japan and, practically, all the powers of Europe. It is one of the oldest of international scientific associations. The delegates to the meetings report progress, and compare methods and results, and endeavor to strengthen such undertakings as the Cape to Cairo Arc of the Meridian and the junction of the Great Trigonometric Survey of India with the Russian Survey. To carry out this last piece of work the association covets the coöperation of China and hopes that that ancient empire will ultimately join the other powers in the undertaking.

Among the tasks undertaken by the association is the determination of the variation of latitude. For this purpose, it maintains six small observatories in the northern hemisphere, two of which are in this country and are under the direction of the Superintendent of the Coast and Geodetic Survey.

Two years ago the astronomer in charge of the Observatory at Gaithersburg, Md., proposed the construction of a Zenith tube for photographically determining the variation of latitude and, at the author's request, the association gave about $2500 for the purpose. The instrument was constructed in this country, has been mounted, and the preliminary results indicate that a step in advance has been taken by securing a higher degree of accuracy, than was before attainable, with a considerable simplification of methods.

The association meets once in three years and the principal countries in Europe have vied with each other in extending invitations for meeting in their capitals. Although the Coast and Geodetic Survey has taken an honorable part in these meetings it has never had the privilege of extending the hospitality of this country to the association. Mention of this fact is made with the same embarrassment that the author feels in representing a great nation at such meetings, and having to maintain silence when the different nations of Europe are competing for the place of meeting.

The Geodetic Level. The levelling instrument, developed in the Coast Survey, with which nearly all engineers are familiar, may be called a binocular level because there is a telescope attachment by means of which the level is read by the observer without shifting his position. The level bubble itself is set into the telescope tube so as to be near the line of sight. Furthermore, the telescope tube is made of the alloy of nickel and steel called "invar" which has a coefficient of expansion of only about one-tenth that of steel.

The introduction of this level has added greatly to the accuracy of the operations, the speed with which the best grade of work can be done has been much increased, and the cost correspondingly reduced.

In a slightly modified form it is in use in the Geological Survey. The Egyptian, Australian, and Canadian governments have also introduced it, and a recent report of the Director of the Great Trigonometric Survey of India shows that a Commission was appointed to report on its merits, and that as a result of the report all their parties will soon be equipped with it.

The Coast Survey is not the only government agency engaged in leveling. The Survey confines itself to running standard lines which it connects with mean sea-level, at various points along the coasts, the datum planes being derived from long series of tidal observations. The coöperation between various agencies of the government is shown by the fact that all the principal lines of level, those by the Geological Survey, by the Deep Waterways Commission, the Mississippi and Missouri River Commissions, and by the Lake Survey, are utilized by the Coast and Geodetic Survey in a general adjustment which will serve for all time as the basis of heights in this country. The value of this work will continue to increase from generation to generation. The elevations of the bench marks in the precise level net east of the Mississippi River will be held as published, while the next adjustment will fix the final elevations of the bench marks in the net of precise leveling to the westward of that river.

One phase of leveling, which is of scientific interest, was connecting the mean tide level at San Diego with mean tide level at Seattle, where a difference of over three feet was found. Had the levels been run along the sea-shore from San Diego to Seattle, no difference would have developed, assuming the work to have been accurately done. But as the lines were run up to and over high plateaus in the interior, and down again, it was found that the orthometric correction had to be applied, and this brought the operations into perfect accord. That is, the apparent difference of level was due to the route followed. This results from the consideration that two water-level surfaces, one above the other, will not be parallel as one travels north or south. In running east and west it makes no difference, but in running north and south this becomes a measurable quantity.

Our Northern Boundaries. The Superintendent of the Coast and Geodetic Survey is Commissioner for the demarcation of the Alaskan boundary, and for that portion of the northern boundary of the United States extending from the Pacific Ocean to the Bay of Fundy, with the exception of the boundary running through the Great Lakes. The beginning of the settlement of the boundary, through Passamaquoddy Bay, goes back to the Treaty of Peace of 1782; the settlement of disputed questions was again provided for, in the Treaty of Ghent, in 1814, but certain portions of the line were not settled until last year. Some portions of the line have never been laid down on any map but, generally speaking, the duty of the present commission is merely to fix up upon the ground, by surveys and monuments, the line where it has not been heretofore fixed with that particularity with which boundaries should be marked. The distance from the Pacific Ocean to Passamaquoddy Bay, along the boundary, is about 3800 miles, 1200 miles of which are water boundary, running through the Great Lakes. When the boundary to the west of the Lake of the Woods was marked it was supposed that no one would ever feel any particular interest in this unsettled region, and that provisional marks or monuments at long intervals would suffice for all time. Needless to say, the settlement of this country brought with it irritating questions as to the precise location of the boundary line. For the settlement of these questions a joint treaty covering the boundary from end to end was exchanged and ratified, in 1906, although prior to that time an international commission had been at work in a less formal way in restoring old monuments and tracing the boundary where international questions had made it necessary. The triangulation has been extended from the Pacific Ocean to the summit of the Rocky Mountains, and this part of the line has been monumented with aluminum bronze monuments.

To the east of the Rocky Mountains this same thing has been done, at the present time, to within 100 miles of the Lake of the Woods, and the whole boundary has been carefully mapped, for a short distance, on each side of the line. Progress has also been made in surveying the thickly wooded region extending from Lake Superior to the Lake of the Woods, and further to the east the monumenting and surveying is in progress along the northern boundary of Maine.

All this work is done by international coöperation, under two commissioners, one representing Great Britain and the other the United States.

Probably more has been said of the demarcation of the Alaskan boundary than of this northern boundary. The Alaskan boundary work has been going on simultaneously ever since the tribunal, in London, in 1903, settled the vexed question of the location of the southeastern boundary of Alaska. The greater portion of this line runs from mountain peak to mountain peak over inaccessible fields of snow and ice. Starting on the 141st meridian, a little to the west of Mount St. Elias, the line follows these Alpine summits to the head of Portland Canal, and down that canal to the vicinity of the historic parallel "Fifty-four, forty, or fight," and thence to the Pacific. Wherever it was possible to place monuments it was done, especially at all river crossings in the passes; all of the mountain peaks were trigonometrically located and the region was mapped photo-topographically. From photographs taken at determined trigonometric points maps were made by geometric construction. It is hardly necessary to say that the reports of the surveyors, who conducted this difficult and hazardous enterprise, are full of thrilling adventure, but only two lives have so far been sacrificed. Many of the men had the unpleasant experience of dropping into glacial chasms, from which they were rescued, but the two men who lost their lives fell into an abyss and their bodies were never recovered. The field work of the southeastern Alaskan boundary has been nearly completed. The other part of the Alaskan boundary extends from the vicinity of Mount St. Elias, northward along the 141st meridian to the Arctic Ocean, a distance of about 600 miles. There never has been any international dispute as to that part of the boundary, which was defined by the treaty of 1826 between Great Britain and Russia. But for reasons not necessary to give here a new treaty was made in 1906 by which the Commissioners were instructed to determine, by means of the telegraph, a point on the 141st meridian and to trace a north and south line through it, extending from the Arctic Ocean to the southernmost point of this boundary. The physical difficulties of this work are very great owing to the difficulties of transportation and the shortness of the season. The difficulties of transportation are illustrated by the experience of two years ago, when the parties had to march 300 miles to get to the working ground. The plan of the work which is being carried out contemplates a north and south transit line along this meridian, cutting a line through the timber, planting aluminum bronze monuments in rock or cement bases at intervisible intervals, carrying on a triangulation which spans the boundary and the topographic mapping of a strip about two miles wide on each side of it. Aside from the immediate purpose of the delimitation, this work will serve as an admirable basis for coördinating the land and economic surveys which will follow in another generation or two.

The southern limit of the work accomplished along the 141st meridian is at Mt. Natazhat. It is only a provisional limit for it will be necessary to go about 90 miles farther south, through the mountainous ice field which lies to the north of Mount St. Elias.

Just what can be accomplished there remains to be seen, for it is plainly useless to plant monuments on moving glaciers.

Toward the north, in the land of the Midnight Sun, the transit line has crossed a range of mountains whose crests are estimated to be about 7,000 feet high, distant about twenty miles from the coast. The last station is about seven miles from the Arctic Ocean. The topography, triangulation, and monumenting have not been finished quite so far, and the details of this work are not yet at hand, as the parties are only just returning after a very successful season. The season was marred only by an outbreak of smallpox among the Indians which, as a matter of self-protection as well as for humanitarian reasons, engrossed the care and attention of the American Chief Engineer and his surgeon all summer.

The Survey is giving special attention to the publications, for the use of engineers, of the geographic coördinates, the descriptions of the trigonometric stations, and the leveling and magnetic results. The daily mail at the Survey office impresses one with the widespread and increasing demand for this information, and taxes the ability of the office to keep pace with it. Each division is in charge of an expert and the result is that the methods of the Survey compel the close attention and study of other nations and often serve as a model for them.

INVESTIGATION OF ILLINOIS SOILS

BY

CYRIL G. HOPKINS

The Agricultural Experiment Station of the University of Illinois has been engaged in the investigation of Illinois soils for about ten years. These investigations are conducted by soil surveys, by analyses of representative samples of the various types of soil found in the State, and by culture experiments which are carried on to some extent by pot cultures in glass houses, in large jars filled with different types of soil treated and cropped in different ways, and much more extensively by field experiments which are in progress on thirty-five different soil experiment fields, aggregating about 800 acres of land on representative soils in various parts of the State.

A general soil survey of the entire State was first made in which fourteen great soil areas were located, based upon soil formations,